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NATIONAL COMMUNICATIONS SYSTEM

TECHNICAL INFORMATION BULLETIN 89-3

EXPERT SYSTEM ENHANCEMENT TO THE RESOURCE ALLOCATION MODULE OF THE NCS EMERGENCY PREPAREDNESS MANAGEMENT INFORMATION SYSTEM (XTRAM)

AUGUST 1989

OFFICE OF THE MANAGER
NATIONAL COMMUNICATIONS SYSTEM
WASHINGTON, D.C. 20305

August 1989 Final

Expert System Enhancement to the Resource Allocation Module of the NCS Emergency Preparedness Management Information System (XTRAM) C-DCA100-88-R-0070

Delta Information Systems, Inc.
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Horsham, PA 19044

National Communications System
Office of Technology & Standards
Washington, DC 20305-2010 NCS TIB 89-3

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The function of XTRAM is to serve as an advisor or consultant to the Resource Allocation Officer (RAO) in allocating scarce communications resources, especially in time of national emergency. XTRAM is designed to obtain pertienent information from EPMIS and produce recommended resolutions to requests for telecommunication services, freeing the RAO from much of the data analysis process. XTRAM is an artifical intelligence report system, and was developed using the Automated Reasoning Tool.

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AUGUST 1989

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FOREWORD

The National Communications System (NCS) is an organization of the Federal Government whose membership is comprised of 23 Government entities. Its mission is to assist the President, National Security Council, Office of Science and Technology Policy, and Office of Management and Budget in:

- The exercise of their wartime and non-wartime emergency functions and their planning and oversight responsibilities,
- The coordination of the planning for and provision of National Security/Emergency Preparedness communications for the Federal Government under all circumstances including crisis or emergency.

In support of this mission the NCS has developed the Emergency Preparedness Management Information System (EPMIS) to permit the Manager, NCS and the designated Resource Allocation Officer (RAO) to respond effectively to declared national emergencies. This is in direct support of the survivability and endurability objectives addressed by Executive Order 12472 and National Security Decision Directive 97. This report represents a system design specification of the Expert System Enhancement to the Resource Allocation Module (XTRAM) of EPMIS. XTRAM will assist the RAO in utilizing EPMIS for allocation and use of limited telecommunication assets in times of crises and emergencies.

Comments on this TIB are welcome and should be addressed to:

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EXPERT SYSTEM
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1.0 INTRODUCTION

The Office of the Manager, NCS, requires timely, accurate information about the status of communications resources during national emergencies and declared disasters. This led to the realization that an automated decision support system would be useful to NCS Emergency Management Teams, which play a significant role in the monitoring and resolution of such situations.

The Emergency Preparedness Management Information System (EPMIS), which is designed to allow the Manager, NCS, to respond to declared national emergencies, is an integral part of the National Emergency Telecommunications Management System. EPMIS is a user-oriented, decision-support tool designed to assist the Manager, NCS, in the performance of his assigned emergency communications management mission by providing timely information about the residual communications capabilities and the outstanding National Security Emergency Preparedness (NSEP) communications requirements of the nation.

Delta Information Systems was contracted to develop an Expert System Enhancement to the Resource Allocation Module (XTRAM) for EPMIS. The function of XTRAM is to serve as an advisor or consultant to the Resource Allocation Officer (RAO) in allocating scarce communications resources, especially in times of national emergency. The RAO has the use of the Emergency Preparedness Management Information System (EPMIS), which is basically a custom-designed file management system that keeps track of the availability of communications resources and the demands upon them. XTRAM is

designed to obtain pertinent information from EPMIS (just as the RAO would do without XTRAM) and produce recommended resolutions to requests for Telecommunications services, freeing the RAO from much of the data analysis process.

EPMIS was developed using the INGRES relational database management system, and currently functions on a Digital Equipment Corporation (DEC) MICROVAX II multi-user computer system operating under the VMS operating system. Many users can access the EPMIS database concurrently. Users interface with the EPMIS system by means of text-based menus presented on a computer monitor, with keyboard driven data entry; that is, users must press keys on a computer keyboard in order to interact with the EPMIS program.

XTRAM is an artificial intelligence expert system, and was developed using the Automated Reasoning Tool (A.R.T.). XTRAM currently runs on DEC VAXstation II single-user, multi-tasking workstation. The VAXstation has a 19" high-resolution monitor, standard keyboard, and a three button mouse. The XTRAM program takes full advantage of the VAXstation features. XTRAM is basically a mouse driven program with little keyboard interaction needed. The user moves a pointer on the monitor (via the mouse) to an option he wants to perform, and pushes one of the buttons on the mouse in order to select the option.

Since the VAXstation is multi-tasking, more than one program can be controlled and displayed on the monitor concurrently. A full EPMIS window can be displayed on the monitor while the XTRAM program is running. If the user wishes to access EPMIS at any time while the

XTRAM program is running (or idle), the user needs to just move the mouse pointer to the EPMIS window and press a mouse button.

Currently, EPMIS and XTRAM are running on two physically separate computer systems communicating through a data link. The purpose of this report is to present the results of an investigation in which methods to integrate the EPMIS and XTRAM software systems into one software system, residing on one computer, were evaluated.

2.0 SUMMARY

2.1 Overview

In this report, two alternatives are described in which the XTRAM program can be integrated in to the existing EPMIS environment. The EPMIS environment consists of two software modules (EPMIS application program and Damage Assessment Module) and a database residing on a super-micro MICROVAX II computer and a third module (Mapping Graphics Module) residing on an 80386 PC micro computer used as an EPMIS terminal. All of the modules in the EPMIS environment must access the EPMIS database at one time or another. The 80386 machine and the MICROVAX II communicate through a communications link. This report analyzes the issues and topics regarding integration taking into consideration the existing/planned purchases of hardware, software and on-going integration efforts.

The first alternative (Alternative 1) consists of the XTRAM program executing on the 80386 PC along with the Mapping Graphics Module, communicating with the EPMIS database through a network communications link.

The second alternative (Alternative 2) consists of the XTRAM program executing on the MICROVAX II along with the EPMIS database, Damage Assessment Module, and EPMIS application program.

Either alternative would provide the required functionality needed for an integrated system, but the alternatives differ in performance, price and features. This report addresses all factors involved in selecting the alternatives, and an in depth description

of each alternative along with comparisons between the two alternatives.

2.2 Recommendations

The issue which clearly separated the two alternatives mentioned above is performance. Of the two system alternatives mentioned, Alternative 1 consists of XTRAM running on a 80386 PC connected to the MICROVAX II, and Alternative 2 consists of XTRAM running on the MICROVAX II along with the EPMIS application program and Damage Assessment Module. In both alternatives the NEXPERT OBJECT expert system development tool is recommended for XTRAM development.

When considering the 80386 vs. the MICROVAX II approach, the performance of the 80386 approach should be significantly higher due to the higher processing speed of the 80386 (even when the overhead of the communications link is taken into consideration). The performance increase in using NEXPERT on a PC is estimated at 10 to 15 times the present XTRAM performance level.

As more users, each potentially using XTRAM, use the system, more processing power becomes necessary. The processing of XTRAM (possible multiple XTRAMs) in the MICROVAX II, along with processing needed by the other modules executing on the MICROVAX II, would not only severely degrade XTRAM performance, but also degrade performance of the other modules which access the EPMIS database.

The added processing power of a 80386 in addition to the MICROVAX II will give the entire system added performance. XTRAM processing will not interfere with EPMIS performance on the MICROVAX

II with the exception of database accesses required by XTRAM. When many EPMIS/XTRAM users are using the system, XTRAM will be processing on multiple 80386 machines (5.5 MIPS each) instead of many XTRAM processes on a single MICROVAX II (0.9 MIPS).

Of the two alternatives described, Alternative 1 is recommended for XTRAM integration. With the advantage in both price/performance and accommodations for future plans (fly-away), the 80386 XTRAM technique outweighs the MICROVAX approach.

3.0 XTRAM/EPMIS DESCRIPTION

3.1 EPMIS

The Emergency Preparedness Management Information System (EPMIS), an integral part of the National Emergency Telecommunications Management System, is designed to allow the Manager, NCS, to respond to declared national emergencies. EPMIS is a user-oriented, decision-support tool designed to assist the Manager, NCS, in the performance of his assigned emergency communications management duties by providing timely information about the residual communications capabilities and the outstanding National Security Emergency Preparedness (NSEP) communications requirements of the nation. The following sections describe the present and proposed future implementations of EPMIS.

3.1.1 Present Implementation

EPMIS was developed using the INGRES relational database management system and currently functions on a Digital Equipment Corporation (DEC) MICROVAX II multi-user computer system running under the MicroVMS operating system (see Table 3-1). The multi-user system environment allows several users access to the EPMIS database concurrently. The EPMIS user interface consists of a text-based menu system, presented on a DEC VT-220 monitor, and keyboard-controlled data entry (i.e. users must press keys on a computer keyboard in order to make menu selections and/or enter data).

In the present implementation, EPMIS and XTRAM can be run concurrently on separate machines. While EPMIS is running on the

Table 3-1 - EPMIS Hardware/Software Configuration

Hardware	
System	: MicroVAX II
Memory	: 5 Mb
Storage Capacity	: 142 Mb
Processor Speed	: 0.9 MIPS
Communications	: Ethernet, Asynchronous RS-232
Display Type	: VT-220
Portability	: Non-Portable
Software	
Operating System	: MicroVMS 5.0
Communications	: DecNET
Applications	
Database Management	: INGRES RDBMS
Database Communications	: INGRES/NET
High-level Language	: VAX FORTRAN

MicroVAX II, XTRAM, running on a VAXStation II workstation, can access EPMIS via an Ethernet connection by emulating an EPMIS terminal. As far as EPMIS is concerned, XTRAM appears to be a typical EPMIS terminal. The multi-windowing user interface on the XTRAM VAXStation II allows the user to open an XTRAM window and an EPMIS window concurrently. However, because of the two computer configuration and special terminal requirements, XTRAM cannot run from a standard EPMIS terminal.

3.1.2 Proposed Changes

The original EPMIS environment that the current XTRAM communicates with will have changed by the time the EPMIS-XTRAM integration is performed. The EPMIS software package has already

changed versions from 3.0 to 4.0. Also, the integrations of EPMIS modules other than XTRAM are presently underway and are expected to be finished prior to the EPMIS-XTRAM integration.

Prior to the XTRAM integration, EPMIS will be integrated with a new Damage Assessment Module and a Mapping Graphics Enhancement. The Damage Assessment Module, developed by Roland and Associates, will provide EPMIS with improved blast, radiation, and fall-out effects assessment capabilities. It will be implemented on the EPMIS MicroVAX II in a direct software-to-software integration with EPMIS. The new damage assessment module is a more complex damage modeling module than the one that presently exists in EPMIS. While an official Integration Control Document (ICD) for the Damage Assessment Module integration was not available for this study, it appears that the integration of the Damage Assessment Module will not affect the integration of XTRAM. The physical integration of the DAM is scheduled for mid June 1989.

The Mapping Graphics Enhancement, developed by TITAN Systems, will provide EPMIS with a user interface capable of graphically depicting the location and status of telecommunication systems and networks, communication facilities, and other critical resources and assets. The enhancement will also allow the EPMIS user to update the status of resources in the EPMIS data base. The Mapping Graphics Enhancement is tentatively scheduled to be implemented on a 20 Mhz 80386-based personal computer (see Table 3-2). An official ICD for the Mapping Graphics Enhancement was not available for this study. The mapping graphics integration may have an impact on the planned

Table 3-2 - EPMIS PC Hardware/Software Configuration

Hardware	
System	: Compaq 386
Memory	: 10 Mb
Storage Capacity	: 100 Mb
Processor Speed	: 20 MHz, 4.5 MIPS
Communications	: Asynchronous RS-232
Display Type	: VGA Gas Plasma
Portability	: Portable
Software	
Operating System	: MS-DOS 3.3
Communications	: RTI PC-Link
Applications	
Mapping Graphics	: Titan
Terminal Emulation	: DEC VT-220

XTRAM integration. In one of the integration alternatives proposed in this study, the XTRAM program would execute in an 80386 environment along with the mapping graphics module. If the government selects the XTRAM 80386 approach, close coordination between Delta Information Systems and TITAN Systems will be necessary for a successful integration.

3.2 XTRAM

The Expert System Enhancement to the Resource Allocation Module (XTRAM) for EPMIS is designed to serve as an advisor or consultant to the Resource Allocation Officer (RAO) in allocating scarce communications resources, especially in times of national emergency. Currently, the RAO has the use of the Emergency Preparedness

Management Information System (EPMIS), which is basically a custom-designed file management system that keeps track of the availability of communications resources and the demands upon them. XTRAM is designed to obtain pertinent information from EPMIS (just as the RAO would do without XTRAM) and produce recommended resolutions to requests for telecommunications services, freeing the RAO from much of the data analysis process.

3.2.1 Present Implementation

XTRAM is an artificial intelligence expert system developed using the Automated Reasoning Tool (A.R.T.). XTRAM currently runs on a DEC VAXstation II single-user, multi-tasking workstation running under the MicroVMS operating system (see Table 3-3). The VAXstation has a 19" high-resolution monitor, a standard keyboard, and a three button mouse, all of which are incorporated into the XTRAM user interface. XTRAM is basically a mouse-driven, menu-based program with little keyboard interaction required. Using the mouse, the XTRAM user moves a pointer on the monitor to a menu option he wants to perform, and clicks one of the buttons on the mouse in order to select the option.

Since the VAXstation is multi-tasking, more than one program can be controlled and displayed on the monitor concurrently. Each program is displayed in its own operating window; the workstation user can switch between windows by moving the mouse cursor into the window and clicking one of the mouse buttons. This feature allows the concurrent display of an XTRAM session and an EPMIS session on

Table 3-3 - XTRAM Hardware/Software Configuration

Hardware	
System	: VAXStation II
Memory	: 16 Mb
Storage Capacity	: 230 Mb
Processor Speed	: 0.9 MIPS
Communications	: Ethernet, Asynchronous RS-232
Display Type	: VR-260 19" High-resolution graphics
Portability	: Non-Portable
Software	
Operating System	: MicroVMS 5.0
Communications	: DecNET
Applications	
Expert System	: LISP-based ART 3.2
Database Management	: INGRES RDBMS
Database Communications	: INGRES/NET
High-level Language	: VAX C

one monitor, giving the user, to a limited extent, an integrated EPMIS-XTRAM system. If the XTRAM user wishes to access EPMIS at any time, the user needs only to move the mouse cursor to the EPMIS window and click a mouse button.

In the present implementation, EPMIS and XTRAM can be run concurrently on separate machines. While EPMIS is running on a MicroVAX II, XTRAM, running on the VAXStation, can access EPMIS via an Ethernet connection by emulating an EPMIS terminal. As far as EPMIS is concerned, XTRAM appears to be a typical EPMIS terminal. As stated earlier, the VAXStation's multi-tasking feature also allows the user to open one (or more) EPMIS terminal sessions which also communicate with the EPMIS MicroVAX II via the Ethernet connection.

3.2.2 Proposed Changes

The original EPMIS environment that the current XTRAM communicates with will have changed by the time the EPMIS-XTRAM integration is performed. The EPMIS database software package has already changed versions from 3.0 to 4.0. Changes to XTRAM will be limited to modifications required to accommodate the new EPMIS database structure (e.g. field changes, additions, and deletions).

3.3 Integrated EPMIS-XTRAM

3.3.1 System Requirements

One of the system requirements of the integrated EPMIS-XTRAM is that all EPMIS modules function together in an integrated environment and that all modules are accessible from a single user terminal. That is, a user must be able to invoke EPMIS, XTRAM, the Damage Assessment Module, and the Mapping Graphics Enhancement from a single EPMIS terminal. A second system requirement for the integrated EPMIS-XTRAM is that the system must be multi-user, with each user having full EPMIS capabilities.

3.3.2 Functionality

3.3.2.1 Proposed Integration

The proposed integrated XTRAM/EPMIS system would have XTRAM and EPMIS (including damage assessment and mapping graphics) running from a single terminal. A dedicated XTRAM computer terminal would not be needed and XTRAM would be accessible from every EPMIS terminal.

Also, the concurrent execution of the EPMIS and XTRAM programs would be preserved.

The existing XTRAM user interface consists of a series of graphics windows with mouse-cursor control over the windows. Very little keyboard interaction and knowledge of computers is necessary to operate the XTRAM program. One goal for integration is to preserve the functionalities of the existing XTRAM user interface as much as possible.

The proposed EPMIS-XTRAM integration alternatives (to be discussed in Section 4.0) were designed so that EPMIS modifications would be kept to a minimum. The extent of the modifications to the EPMIS software environment would be limited to adding an XTRAM option to the EPMIS Main Menu which, when selected, would initiate an XTRAM session running concurrently with EPMIS. Additional modifications are dependent upon which integration alternative is implemented.

EPMIS-XTRAM Integration Alternative 1, in which XTRAM would be implemented on an 80386-based PC along with the Mapping Graphics Enhancement, would require significant hardware and software modifications to the EPMIS PC environment to implement XTRAM. The integrated PC system proposed in Alternative 1 is presented in Table 3-4. This integration option would reduce the portability of the EPMIS PC terminal environment, but would greatly increase its capabilities. Each EPMIS PC terminal would have full XTRAM capabilities, with all of the related processing being performed by the 5.5 to 6.5 MIPS PC.

Table 3-4 - Proposed EPMIS-XTRAM Integration Plan 1 System

Hardware	
System	: Compaq 386/25
Memory	: 13 Mb
Storage Capacity	: 110 Mb
Processor Speed	: 25 MHz, 5.5 MIPS
Communications	: Ethernet (DEPCA), Asynchronous RS-232
Display Type	: VGA Color Graphics
Portability	: Non-Portable (Desktop)
Software	
Operating System	: MS-DOS 3.3
Communications	: DECNet DOS, MS-Net, INGRES/NET
Applications	
Mapping Graphics	: Titan
Expert System	: NEXPERT OBJECT
Terminal Emulation	: VT-220 (DEC PCSA)
Multitasking	: MS-Windows/386 or Desqview
User Interface	: NEXPERT windows/mouse building tools
High-level Language	: MicroSoft C

EPMIS-XTRAM Integration Alternative 2, in which XTRAM would be implemented on the EPMIS MicroVAX II, would require significant hardware and software modifications to the EPMIS MicroVAX II environment to implement XTRAM. The integrated MicroVAX II system proposed in Alternative 2 is presented in Table 3-5. This integration option would preserve the portability of the EPMIS PC terminals, but would put the burden of processing multiple XTRAM sessions on the 0.9 MIPS MicroVAX II.

Because the proposed EPMIS-XTRAM integration alternatives were designed so that EPMIS modifications would be kept to a minimum, the

Table 3-5 - Proposed EPMIS-XTRAM Integration Alternative 2 System

Hardware	
System	: MicroVAX II
Memory	: 13 Mb
Storage Capacity	: 300 Mb
Processor Speed	: 0.9 MIPS
Communications	: Ethernet, Asynchronous RS-232
Display Type	: VT-220
Portability	: Non-Portable
Software	
Operating System	: MicroVMS 5.0
Communications	: DECNET
Applications	
Database Management	: INGRES RDBMS
Database Communications	: INGRES/NET
Expert System Shell	: NEXPERT OBJECT
User Interface	: NEXPERT Text window building tools
High-level Language	: VAX C

integration alternatives proposed place the bulk of the modification burden on XTRAM. The modifications to the XTRAM software environment include converting the XTRAM expert system software to a new expert system shell platform (NEXPERT OBJECT) and modifying the operator interface to suit the new hardware/software implementation. Additional modifications are dependent upon which integration alternative is implemented.

In Alternative 1, the XTRAM expert system software, presently implemented in the LISP-based A.R.T. 3.2 expert system shell, would be converted to the C-based NEXPERT OBJECT expert system environment. Although A.R.T. 3.2 was determined to be the best expert system shell available for the VAXStation II when XTRAM was developed, the current study has revealed that NEXPERT is, overall, the best shell currently

available, for both PC and VAX implementations. Because NEXPERT's inference engine is similar to that of A.R.T.'s, the conversion effort would be quite reasonable.

The 80386-based PC hardware environment of Alternative 1 would require significant modifications to the XTRAM user interface in terms of implementation; however, the actual XTRAM user interface would not change significantly. Through Desqview, "C" graphics libraries, and DECNet DOS, the VAXStation II multi-windowing, multi-tasking user environment can be preserved.

In Alternative 2, as in Alternative 1, the XTRAM expert system software, presently implemented in the LISP-based A.R.T. 3.2 expert system shell, would be converted to the C-based NEXPERT OBJECT expert system environment. The MicroVAX II hardware environment of Alternative 2 would require significant modifications to the XTRAM user interface in terms of both implementation and appearance. Because the MicroVAX II terminals would be strictly VT-220 text displays, NEXPERT's text window user interface building tools would be used to implement a text-based, keyboard-driven interface similar to that of EPMIS. EPMIS-XTRAM concurrent operation would be implemented via the MicroVMS multi-tasking capabilities, but only one application would be displayed at a time. Switching between EPMIS and XTRAM would be accomplished through menu options.

3.3.2.2 Fly-away

Current integration tasks involving the use of 80386-based PCs as EPMIS terminals are significant steps toward EPMIS portability. These PCs are small, relatively inexpensive, and becoming very powerful. PC technology, as well as computer technology in general, is progressing very rapidly. Significant advances in PC portability continue to be made. With the announcement of Intel's 80486 CPU (which is completely compatible with the 80386 CPU), capable of 15-20 MIPS at the introductory clock speeds, it will not be long until the 80486 technology is made portable.

Another technological advance occurring in the PC world is the advancement of operating system software to run on these machines. Currently, the most accepted PC operating system is DOS. DOS is a single-user/single-tasking operating system, which limits the ability to have multiple users access a single PC without the use of additional software. DOS also has a limit of 640K addressable memory. There are ways around these barriers, but DOS was not meant to operate in a large memory/multi-user environment.

Other multi-user/multi-tasking operating systems that have been introduced to the PC environment are UNIX and OS/2. These operating systems are relatively new to the PC environment, however, and many software packages (database, networking, graphics, etc) that are necessary to build a system such as XTRAM are not supported under these operating systems at the present time. Many software vendors are presently working towards making their products available under these operating systems.

At the present time, the ability to place the entire EPMIS system (all modules included) in a portable environment providing all required EPMIS functionality is not feasible due to hardware constraints, operating system constraints, and software availability. With advances in hardware and software technology, however, the EPMIS database could be moved to into a portable environment, making the entire system portable. Taking steps towards the PC environment can only be beneficial to the entire EPMIS program.

3.3.3 Performance

Because all the modules (EPMIS application, damage assessment, mapping graphics, and XTRAM) access the EPMIS database, the performance of all modules is dependent upon the database access performance. If the EPMIS database access is slowed by other processing going on in the same computer, performance of all modules will suffer. There are two basic ways to keep the database access as fast as possible:

Put the entire EPMIS system on a single computer which is fast enough to handle the processing of all modules and database access;

Reduce, as much as possible, secondary processing (non-database access) on the same computer as the database accessing (distribute processing).

3.3.3.1 Hardware

The proposed EPMIS integrated system is quite different from the original EPMIS system. This new EPMIS has increased hardware needs. The system is also more complex than previously thought. The addition of mapping graphics, XTRAM, and a more complex damage assessment module put more of a strain on the existing EPMIS hardware than the original EPMIS system did. Although physically possible, the addition of all of these modules into the present EPMIS hardware would degrade current performance significantly. There are two basic ways to integrate all of the EPMIS modules and not degrade system performance.

One way would be to place all modules on one computer powerful enough to handle all modules. Although this approach is possible with present technology, the integrated system would be no closer to portability than it is today. In addition, when considering the existing EPMIS hardware along with hardware still on order as well as time and money spent towards on-going integration efforts, this alternative would significantly increase the costs of the EPMIS-XTRAM integration and would not be feasible at the present time.

A second, more practical technique would be to split the processing between multiple computers. In this approach, the database, for example, would reside on one computer, and other CPU-intensive modules would reside on a second computer. The pre-XTRAM integrated EPMIS system is configured this way. The MicroVAX II runs the EPMIS database, and 80386-based PCs running the graphics

applications are used as terminals; each EPMIS user would have an 80386 processor, and a slice of the MicroVAX II processor.

3.3.3.2 Software

The proposed EPMIS integrated system is quite different from the original EPMIS system. This new EPMIS has increased software performance requirements. The system is also more complex than previously thought. The addition of mapping graphics, XTRAM, and a more complex damage assessment module put more of a strain on the existing EPMIS hardware than the original EPMIS system did. Thus, the XTRAM program performance must be improved to minimize its hardware requirements, freeing more processing power for the other EPMIS modules. In particular, the expert system shell must be upgraded to improve its performance.

The present XTRAM system was built using LISP-based ART in a workstation environment. LISP-based ART, and LISP-based shells in general, are excellent for rapid prototyping and development. However, LISP-based shells consume large amounts of computer resources and typically run very slow in a conventional computing environment. LISP-based environments are also not very portable across hardware platforms.

"C"-based shells, on the other hand, are typically smaller and faster, and are very portable across hardware platforms. In integrating XTRAM into EPMIS, it is desirable to make XTRAM as fast as possible, and also to be able to run it in a smaller computing environment than it does presently (to accommodate future portability

plans). It is therefore desirable to use a "C" based expert system development shell for integration.

A major factor in the selection of a new expert system shell is the shell's level of compatibility with existing XTRAM code. XTRAM was originally written using LISP-based ART, which runs on workstations. Selecting a shell with a similar rule structure and similar inferencing techniques would simplify the rule conversion necessary for integration. The present XTRAM employs a feature found in LISP-based ART (and many other LISP-based workstation shells) known as hypothetical reasoning. Hypothetical reasoning is a powerful feature found in most high-end shells. It is typically not found in smaller, "C"-based shells due to the large amounts of computer resources needed for its implementation. If the shell chosen for integration does not have hypothetical reasoning, additional rules will have to be developed to compensate.

Another factor affecting the selection of a new expert system shell is the ability of the shell to run on many hardware platforms with little modification. If an expert system shell is portable, an application developed using that shell can easily be transported to other hardware platforms. This is an important feature if a different hardware platform for EPMIS is chosen in the future.

It is important that the shell selected have a good software development environment. A good development environment will speed software development considerably, as compared to a shell that does not provide a good development environment. The shell should also possess adequate user interface building capabilities. Since the

existing graphical XTRAM interface is, to the extent possible, to be preserved, a shell with tools capable of building such an interface is desirable.

Some of the shells available provide built-in database interface facilities. In using these facilities, database queries can be performed from rules. The advantage of a shell that provides this type of facility is the work that can be avoided in building a custom database interface for a particular application from scratch.

The reputation of the selected shell is also important. A shell that has been proven and has been in existence for a long period of time is less likely to cause problems due to software bugs in the shell during development.

4.0 SYSTEM ALTERNATIVES

4.1 General

This section contains the XTRAM system integration alternatives developed from the integration study performed by Delta Information Systems. Each alternative is described in detail, followed by a system design specification including all materials and associated prices of items required to implement each alternative. Following the alternative descriptions is an alternative analysis comparing all alternatives. This is followed by the recommendation of the particular alternative to be used for integration.

Cost/Performance evaluation assumptions

Each system alternative description contains a price performance evaluation for that alternative. Certain assumptions were made in order to perform a uniform evaluation of each alternative.

The first assumption is the existence of a MICROVAX II in its current hardware configuration, and the existence of 80386 machines used as terminals. The evaluation uses relative costs associated with additions of hardware and software necessary for each individual integration alternative. Both alternatives recommend the use of an expert system shell which is common to both alternatives, so the expert system shell performance is not a variable in the evaluation.

4.1.1 Hardware Candidates

The factors that hardware were evaluated on for the XTRAM integration include: existing hardware used for current non-XTRAM integration, ability to run software packages recommended for integration, practicality for future fly-away plans, and key database performance features.

The first, and probably the most important factor considered is the existing hardware presently being used for integration. As mentioned previously, there are current integration tasks occurring at the present time involving the integration of a damage assessment module and mapping graphics module with EPMIS.

The second factor is the ability of the hardware to run key software packages that are recommended for integration.

The third factor is the practicality of the particular hardware platform regarding future fly-away plans. The proposed hardware configuration should provide one step closer towards portability.

The last factor is the performance of the system from a database management point of view. All modules in EPMIS access the EPMIS database at one time or another. In order for optimum performance of the entire system, a hardware configuration which allows for fast database access should be used. The key points in hardware which are critical for fast database access are: Processing speed (MIPS), data bus throughput, and Disk access time. (Note: The disk access time for the existing MicroVAX II is 37 milliseconds which is sub-optimal by today's standards)

4.1.1.1 MicroVAX-Based Systems

An evaluation of the current MicroVAX family was performed in an effort to determine the best EPMIS-XTRAM integration environment. Because the XTRAM expert system application is presently implemented on a VAXStation II, its implementation on a MicroVAX-based system, when combined with the implementation of the EPMIS database, will require the performance of a more powerful MicroVAX. The principal advantage of a MicroVAX implementation of the integrated EPMIS-XTRAM system is that both the XTRAM software and the EPMIS software would be completely compatible with a more powerful VAX. In addition, because both EPMIS and XTRAM would reside on the same machine, database communications between the two would not be limited by a communications link (e.g. Ethernet).

The integrated EPMIS-XTRAM system could be implemented on the present EPMIS MicroVAX II. However, multiple, concurrent XTRAM sessions on the 0.9 MIPS machine would severely degrade the performance of the system. In order to implement both EPMIS and XTRAM on a single MicroVAX, an upgrade to a more powerful machine is required. Two options available that provide two levels of performance above the MicroVAX II are the MicroVAX 3400 and the MicroVAX 3800.

The MicroVAX 3400 operates at 2.4 MIPS, which is approximately 2½ times the CPU performance of the MicroVAX II. In addition, the data throughput of the MicroVAX 3400 is 3 times the throughput of the MicroVAX II, which will greatly reduce the database access times for both XTRAM sessions and EPMIS terminal sessions. The MicroVAX 3400

can be equipped with a maximum of 28 Mb RAM and 900 Mb of disk storage, both significantly higher than the corresponding maximums of the MicroVAX II.

The integrated EPMIS-XTRAM system would require a MicroVAX 3400 equipped with 16 Mb RAM, 300 Mb of disk storage (standard), and a networking package to communicate with the Mapping Graphics Enhancement PC. A MicroVAX 3400 configured as such, with all associated operating system and support software, would be list priced at approximately $66,000.

The MicroVAX 3800 operates at 4.5 MIPS, which is approximately 4½ times the CPU performance of the MicroVAX II. In addition, the data throughput of the MicroVAX 3800 is 4 times the throughput of the MicroVAX II, which will greatly reduce the database access times for both XTRAM sessions and EPMIS terminal sessions. The MicroVAX 3800 can be equipped with a maximum of 64 Mb RAM and 1.2 Gb of disk storage, both significantly higher than the corresponding maximums of the MicroVAX II.

The integrated EPMIS-XTRAM system would require a MicroVAX 3800 equipped with 16 Mb RAM, 300 Mb of disk storage (standard), and a networking package to communicate with the Mapping Graphics Enhancement PC. A MicroVAX 3800 configured as such, with all associated operating system and support software, would be list priced at approximately $105,000.

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4.1.1.2 SUN-Based Systems

An evaluation of the current SUN workstation technology was performed in an effort to determine the best EPMIS-XTRAM integration environment. The XTRAM expert system application is presently implemented on a VAXStation II; the EPMIS database application is implemented on a MicroVAX II. Both XTRAM and EPMIS could be implemented concurrently on a SUN Microsystems machine. The principal advantage of a SUN implementation of the integrated EPMIS-XTRAM system is that new system would be much more powerful. In addition, because both EPMIS and XTRAM would reside on the same machine, database communications between the two would not be limited by a communications link (e.g. Ethernet).

There are several types of SUN computers available that could be employed for the implementation of the integrated EPMIS-XTRAM system, including the SUN-3 series, the SUN-4 series, and the SUN SPARCstation series. The SUN SPARCstation 330 appears to be the most viable candidate for the EPMIS-XTRAM integration. The SPARCstation 330 is a RISC processor-based computer which operates at 16 MIPS*, which is significantly greater than the CPU performance of the MicroVAX II. In addition, the data throughput of the SPARCstation 330's (VME bus) produces 15-20 times the throughput of the MicroVAX II (Q bus), which will greatly reduce the database access times for

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* The performance rating of a Reduced Instruction Set Computer (RISC), measured in MIPS, is not directly comparable to the performance ratings of Complex Instruction Set Computers (CISCs), also measured in MIPS, because RISC machines require more instructions than CISC machines to perform the same task.

both XTRAM sessions and EPMIS terminal sessions. The SPARCstation 330 can be equipped with a maximum of 40 Mb RAM and 1.3 Gb of disk storage, both significantly higher than the corresponding maximums of the MicroVAX II.

The integrated EPMIS-XTRAM system would require a SPARCstation 330 equipped with 16 Mb RAM, 327 Mb of disk storage (standard), and a networking package to communicate with the Mapping Graphics Enhancement PC. A SPARCstation 330 configured as such, with all associated operating system and support software, would be list priced at approximately $42,500.

4.1.1.3 80386-Based Systems

An evaluation of the current 80386-based PC technology was performed in an effort to determine the best EPMIS-XTRAM integration environment. Because the XTRAM expert system application is highly complex, its implementation on an 80386-based PC, when combined with the implementation of the Mapping Graphics Enhancement, will require the performance of a 25 MHz or 33 MHz 80386-based PC. While a 16 MHz or 20 MHz 80386-based PC could handle this load, the response times to user interactions would be less than those of a 25 Mhz machine.

The 33 MHz 80386-based PCs offer an increase in processing power of 25% to 50% over the 25 MHz PCs (7.5 to 8.5 MIPS vs. 5.5 to 6.5 MIPS). This advantage in processing power is somewhat offset, however, by the fact that the 33 MHz PCs are a relatively recent introduction, while the 25 MHz PCs are well established. This fact, coupled with the recent announcement of Intel's 80486 CPU, which

benchmarks at 15-20 MIPS (at 25 MHz, with clock speeds projected to 60 MHz) and will be priced about the same as the 33 MHz 80386 CPU, indicates that the next logical step up from the 25 MHz 80386-based PC would be to an 80486-based PC. The 25 MHz 80386-based PC, therefore, is a better candidate for the EPMIS-XTRAM Integration Alternative 1 system than the 33 MHz PC.

A survey of available 25 MHz 80386-based PCs was performed in which the PCs were evaluated based on several factors, including list price, performance, documentation, setup, ease of use, serviceability, and value. The comparisons were performed on similarly configured systems: 4 Mb RAM, 32 to 256 Kb cache memory, one high-density floppy (except the Northgate PC, which comes with two), a 100 to 150 Mb ESDI hard disk, and a VGA board and monitor.

From a field of eighteen machines, four 25 MHz 80386-based PCs, the Northgate Elegance 3000, the Compaq Deskpro 386/25, the Dell System 325, and the IBM M70-A21 were selected as the leading candidates. Of these four PCs, the Northgate Elegance 3000 was selected as the preferred EPMIS-XTRAM integration platform. The Northgate Elegance 3000 had the highest reported CPU speed of all of the PCs evaluated at 6.2 MIPS, followed by the IBM M70-A21 at 5.8 MIPS, and the Compaq Deskpro 386/25 and the Dell System 325, which tied at 5.6 MIPS.

The Northgate PC offers the best package of standard features of the four the leading candidates. The Northgate PC's 256 Kb cache memory is significantly greater than the IBM M70-A21 PC's 64 Kb cache memory and the 32 Kb cache memories of the Dell System 325 and Compaq

Deskpro 386/25 PCs. The Northgate PC is the only PC tested that comes with MS-DOS 4.01 (or 3.3) installed on the formatted hard disk; the others require a separate operating system purchase. The Northgate PC is also the only PC tested that comes with both a 5¼" 1.2 Mb floppy drive and a 3½" 1.44 Mb floppy drive; the others include only the 5¼" 1.2 Mb floppy drive.

The Northgate PC is the only PC among the four leading candidates to feature a tower design. This tower design includes five free expansion slots (after the installation of I/O, disk controller, and video boards), ten half-height mounting positions (for disk drives), and all controls (power, reset, keyboard disable, key lock, indicator lights) of the front panel. The expansion slots are mounted vertically, allowing easy, top-of-case access to the expansion board cables.

The Dell System PC is housed in a standard AT-style case with six free expansion slots (after the installation of disk controller and video boards) and five half-height mounting positions (for disk drives). The sixth expansion slot is freed because the serial and parallel I/O is included on the mother board. The Dell System PC's controls are somewhat inconvenient; although the indicator lights and the key lock are on the front panel, the power switch is on the rear of the unit and there is no reset switch.

The Compaq PC is also housed in an AT-style case, with three free expansion slots (after the installation of I/O, disk controller, and video boards) and five half-height mounting positions (for disk drives). Compaq also offers an optional disk expansion unit that

allows for up to 1½ Gb of disk storage. The Compaq PC's controls are sparse; there are no indicator lights, key lock, or reset switch and the power switch is at the rear.

The IBM PC is housed in a small footprint case designed to save desk space. However, this small case limits the expandability of the system; it features only three free expansion slots (before disk controller installation) and one full-height mounting position (limiting the disk storage capacity to 300 Mb, the largest available hard disk). The serial and parallel I/O and video are implemented on the mother board, keeping at least two slots free. These slots, however, are Micro Channel slots, for which there are relatively few peripherals available at the present time.

In terms of documentation and serviceability, the Northgate Elegance 3000 again took top honors. Its documentation is well organized, informative, and well-illustrated, and its technical support, which includes next-day on-site service, is quite good. The Northgate PC was found to be the best value among the four candidates, combining the second-lowest list price with the highest performance and best standard features package.

Company and product reputation is another factor considered in the selection of the EPMIS-XTRAM integration system. Compaq is the most well-known among the four candidates; its reputation is built on the reliability and widespread application of the Compaq family of computers. This reputation, however, is more than offset by the list price of the Compaq Deskpro 386/25. The Northgate Elegance 3000 is produced by Northgate Computer Systems, a company with a much lower

profile than Compaq, but with over 20 years experience in the PC computer field.

Because the PC selected will be implementing the Mapping Graphics Enhancement, the question of graphics adapters and monitors was addressed. All of the PCs studied are equipped with VGA boards and multi-scanning monitors in their standard configurations. However, a new generation of VGA video boards, called enhanced or super VGA, provides increased resolution (800x600 vs. VGA's 640x480) at about the same cost as VGA. Although the Mapping Graphics Enhancement presently does not take advantage of this higher resolution, the capability should be provided for in the integration implementation system.

This impacts the selection of the multi-scanning monitor in particular; all but one of the multi-scanning monitors presently available have maximum specified horizontal frequencies of 35 MHz, which is slightly lower than the horizontal frequency required to display super VGA. Only the NEC MultiSync Plus monitor is specified to handle higher frequencies (the MultiSync Plus is also capable of displaying non-interlaced 1024x768 resolution video).

Based upon the evaluations performed in this study, the system described in Table 4-1 was selected as the EPMIS-XTRAM integration development system. The Northgate Elegance 3000 was the highest rated 80386-based PC system in terms of performance, configuration, and value. The 80 Mb SCSI disk drive was selected for its fast (16 ms) access time; 80 Mb of storage was determined to be sufficient for development purposes. The Paradise VGA board was selected for

Table 4-1 - 80386-Based Integrated EPMIS-XTRAM Development System

Hardware	
System	: Northgate Elegance 3000
Memory	: 8 Mb
Storage Capacity	: 80 Mb (SCSI)
Processor Speed	: 25 MHz, 6.2 MIPS
Communications	: Ethernet (DEPCA), Asynchronous RS-232
Graphics Board	: Paradise VGA Graphics
Monitor Type	: NEC Multisync Plus
Portability	: Non-Portable (Tower)
Software	
Operating System	: MS-DOS 3.3 or 4.01
Communications	: DECNet DOS, MS-Net, INGRES/NET
Applications	
Expert System	: NEXPERT OBJECT
Terminal Emulation	: VT-220 (DEC PCSA)
Multitasking	: Desqview w/QEMM
User Interface	: NEXPERT windows/mouse building tools
High-level Language	: MicroSoft C
List Price	: $16,000

its high-quality graphics and overall value. The MultiSync Plus multi-scanning monitor was selected because it allows for future video board upgrade (e.g. to super VGA) without replacing the monitor.

4.1.1.4 Comparison of Hardware Alternatives

Each of the hardware alternatives discussed above has its relative strengths and weaknesses. The two MicroVAX alternatives offer the advantages of total software compatibility and transparent migration to more powerful VAXes for both EPMIS and XTRAM. However,

the two MicroVAX alternatives offer the unfavorable combination of the highest prices and the poorest performances (in terms of CPU speed and data throughput) among the alternative systems. In addition, the MicroVAX alternatives are poor candidates for future fly-away systems; at present, portability is not a design goal for the MicroVAX family of computers.

The SUN SPARCstation 330 alternative offers the best price/performance combination, far outdistancing the other systems in terms of performance. In fact, the SPARCstation 330 would be the leading candidate if the EPMIS-XTRAM integration were being done from scratch; it offers the capability to implement the entire EPMIS system, including XTRAM and the Mapping Graphics Enhancement, on a single machine. However, because the SPARCstation 330 is a RISC machine, none of the existing EPMIS, XTRAM, or Mapping Graphics Enhancement software (without modification) would be transparently compatible with the hardware. In addition, the SUN alternative is not a good candidate for future fly-away systems; at present, portability beyond a desktop model is not a design goal for the SPARCstation family of computers.

The 80386-based PC alternative offers a price/performance combination comparable to that of the SUN alternative ($2667/MIP vs. $2656/MIP) at a much lower overall cost. With the forthcoming advances in PC technology (e.g. the 80486 CPU), a PC-based system will have the capability to implement the entire EPMIS system, including XTRAM and the Mapping Graphics Enhancement, on a single machine. In addition, this fully integrated EPMIS PC could be

contained in a portable enclosure for full fly-away capability. By developing the integrated EPMIS-XTRAM system software on an 80386-based PC now, the transition to the future fly-away environment will be greatly simplified.

Table 4-2 - Price/Performance Comparison of Hardware Alternatives

	MicroVAX 3400	MicroVAX 3800	SPARCstation 330	80386-based PC
CPU Speed, MIPS	2.4	4.5	16(RISC)	5.6 - 6.5
Bus Speed, Mb/s	2.5	3.3	20	8
List Price, $	66,000	105,000	42,500	16,000
Present Porta-bility	Tower	Tower	Tower	Desktop/Tower
Future Porta-bility	Tower	Tower	Desktop	Portable

4.1.2 Expert System Shell Candidates

All expert system shell candidates described are capable of running on all hardware candidates mentioned in the previous section. The factors on which the expert systems were evaluated include operating speed, portability across hardware platforms, level of compatibility with existing XTRAM code, hypothetical reasoning

capabilities, software development environment, user interface building capabilities, built-in database interface facilities, and reputation.

4.1.2.1 ART-IM (Inference)

ART-IM is a "C"-based version of the ART that was used to develop XTRAM. ART-IM is compatible with ART code developed in the LISP-based ART, with the exception of the hypothetical reasoning capabilities. Because Inference produces both ART packages, ART-IM is very compatible with the existing XTRAM code. In addition, ART-IM is approximately ten times faster (on identical hardware platforms) than the LISP-based ART. Since it is written in "C" it would be relatively easy to embed in an existing application; however, ART-IM is a recent introduction into the market, and thus has not yet been proven.

4.1.2.2 KEE (Intellicorp)

KEE is a LISP-based expert system shell that features hypothetical reasoning, a built-in INGRES interface, and other features similar to the LISP-based ART, making it a good candidate for a prototyping environment. However, because it is LISP-based, it requires large amounts of computing resources (e.g. memory, disk space) and is much slower than the "C"-based shells, making it a poor candidate for an implementation environment. Also, since it is written in LISP it would be relatively difficult to embed in an existing application.

4.1.2.3 KES (Software A&E)

KES is a "C"-based expert system shell. KES needs little in the way of computer resources, is very portable, and is well-established in the expert system market. Since it is written in "C" it would be relatively easy to embed in an existing application. One of KES's chief features is that it provides multiple inference engines, which can be used for problems requiring multiple, independent solutions. Since XTRAM is one specific problem, however, this feature is of little value. KES also does not have a very good software development environment at the present time. KES does not provide hypothetical reasoning.

4.1.2.4 NEXPERT OBJECT (Neuron Data)

NEXPERT OBJECT is a "C"-based expert system shell that runs on a variety of platforms. NEXPERT's "C"-based implementation has enabled NEXPERT to be ported to DEC VAXes, IBM PCs, Apollos, Suns, and IBM mainframes. Also, it's "C" implementation makes it 95% source code compatible across hardware platforms. The only differences across hardware platforms are subtle user interface differences. It is one of the most powerful expert system development tools available on a PC. It is well established and has been proven in many applications. It has also received favorable reviews by many AI and PC magazines.

Similarities to the LISP-based ART include a frame based knowledge representation and a data driven architecture. It has a robust mouse/window driven user interface for development, and an

extensive user interface development tool for building a custom user interface for an application.

Although the use of NEXPERT would require coding changes regarding rule conversion, the user interface coding would be simplified compared to other expert system shells. In addition, XTRAM would become very portable, which is a very important feature if an EPMIS hardware platform change were made in the future.

In addition to the features previously mentioned, NEXPERT can also be easily embedded into existing applications with its "callable interface". The ability to easily embed one application into another is an excellent feature that can be used to physically link programs together in one environment. As with other "C"-based expert systems, NEXPERT does not feature hypothetical reasoning; however, NEXPERT does feature built-in INGRES interface capabilities on various hardware platforms. NEXPERT has also received excellent product reviews by many AI and PC magazines.

Table 4-3 - Expert System Shell Comparison

	ART-IM	KEE	KES	NEXPERT
Language	"C"	LISP	"C"	"C"
Similarity to ART	Excellent	Very Good	Good	Good
Hypothetical Reasoning	No	Yes	No	No
Portability	Good	Fair	Excellent	Excellent
User interface building tools	Fair	Very Good	Fair	Excellent
Development environment	Good	Excellent	Fair	Excellent
Reputation	Not Established	Very Good	Good	Excellent

4.2 Alternative Number One

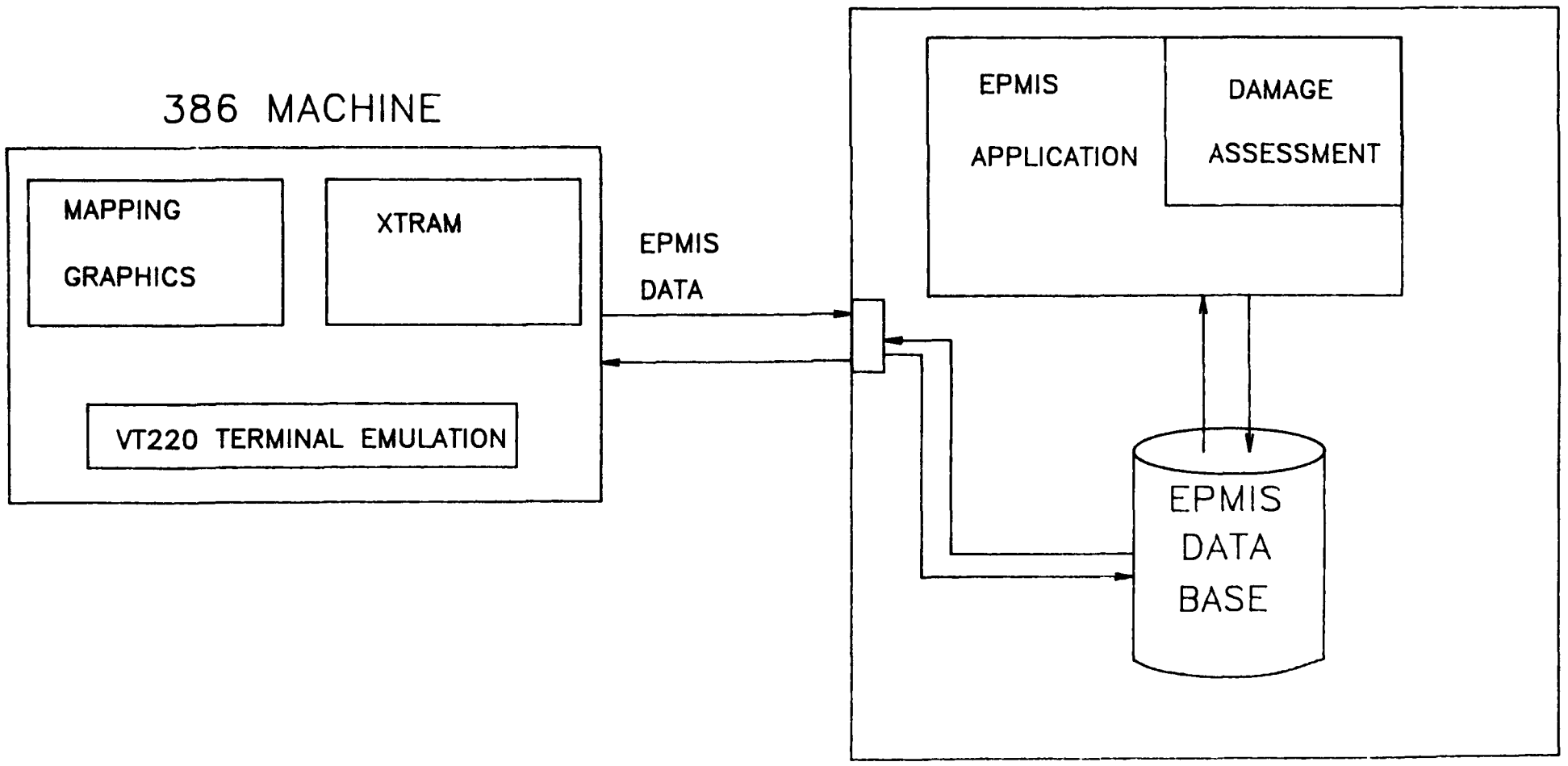
4.2.1 System Design

In the first EPMIS-XTRAM integration alternative, XTRAM would be implemented on an 80386-based PC along with the Mapping Graphics Enhancement. The integrated PC system proposed in Alternative 1 is presented in Table 4-4 and illustrated in Figure 4.1. This integration option would reduce the portability of the EPMIS PC terminal environment, but would greatly increase its capabilities.

Table 4-4 - Proposed EPMIS-XTRAM Integration Alternative 1 System

Hardware	
System	: 80386-based PC
Memory	: 8 Mb
Storage Capacity	: 110 Mb
Processor Speed	: 25 MHz, 5.5 - 6.5 MIPS
Communications	: Ethernet (DEPCA), Asynchronous RS-232
Display Type	: VGA Color Graphics
Portability	: Non-Portable
Software	
Operating System	: MS-DOS 3.3
Communications	: DECNet DOS, INGRES/NET
Applications	
Mapping Graphics	: TITAN
Expert System	: NEXPERT OBJECT
Terminal Emulation	: VT-220
Multitasking	: MS-Windows/386 or Desqview
User Interface	: NEXPERT user interface building tools, "C" graphics libraries
High-level Language	: MicroSoft C

SYSTEM ALTERNATIVE 1



Each EPMIS PC terminal would have full XTRAM capabilities, with all of the related processing being performed by the 5.5 - 6.5 MIPS PC.

In Alternative 1, communications between the EPMIS MicroVAX II and the EPMIS PC terminal could be handled both asynchronously (RS-232 modem, for fly-away applications) and via high performance Ethernet connections (for on-site applications). The XTRAM expert system software, presently implemented in the LISP-based A.R.T. 3.2, would be converted to a C-based expert system environment to increase performance. The hardware and software systems recommended for Alternative 1 are discussed below.

4.2.1.1 Hardware

The hardware requirements for Integration Alternative 1 are detailed in Table 4-4. As discussed in Section 4.1.1, the implementation of XTRAM on an 80386-based PC, in combination with the Mapping Graphics Enhancement, would require the processing power of a 25 MHz or 33 MHz machine. The survey of the presently available 80386-based PCs revealed that a 25-MHz 80386-based, non-portable PC would be the best candidate for the integration. All of the 25 MHz 80386-based PCs examined were similar in terms of performance and features; the selection of the integration PC would therefore be based primarily on price.

A non-portable machine is recommended for the initial EPMIS-XTRAM integration because the configuration required to implement both XTRAM and the Mapping Graphics Enhancement along with a modem, additional memory, CD-ROM etc. on a portable PC is not

currently available. This is true primarily due to clock speed limitations and available slots in portable models. The 25 MHz 80386-based PC, however, will provide an excellent platform for the transition to a portable, or fly-away, integration system when the technology becomes available. The recent announcement of Intel's 80486 CPU (benchmarked at 15-20 MIPS at introduction) is a good indication that portable PCs with the capability to run XTRAM and the Mapping Graphics Enhancement concurrently are not far off. By developing the integrated system on a 25 MHz 80386-based PC, upgrading to an 80486-based portable will require virtually no modifications.

4.2.1.2 Software

4.2.1.2.1 Expert System Shell

NEXPERT OBJECT is an expert system shell that runs on a variety of platforms. NEXPERT's "C" based implementation has enabled NEXPERT to be transported to the DEC VAX, IBM PC, Apollo, Sun, and IBM mainframes. In addition, it is 95% source code compatible across hardware platforms as a result of its "C" implementation. The only differences across hardware platforms are subtle user interface differences. NEXPERT OBJECT is one of the most powerful expert system development tools available for the PC environment. It is well established and proven in many applications. It has also received favorable reviews by many AI and PC publications.

NEXPERT OBJECT shares several similarities with ART that will facilitate the conversion of the XTRAM software from the LISP-based

ART to the "C"-based NEXPERT. These similarities include a frame based knowledge representation and a data driven architecture. NEXPERT has a robust mouse/window driven user interface for development, and an extensive user interface development tool for building a custom user interface for an application.

Although the use of NEXPERT would require more coding changes regarding rule conversion, the user interface coding would be much simpler compared to that of other expert system shells. The conversion to NEXPERT would make XTRAM very portable, an important feature if an EPMIS hardware platform change were made in the future.

In addition to the features previously mentioned, NEXPERT can also be easily embedded into existing applications. The ability to easily embed one application into another is an excellent feature that can be used to physically link programs together in one environment.

The NEXPERT development package running under MS-Windows would be used for development, while the NEXPERT runtime package (protected mode) running under Desqview independent of MS-Windows would be used for XTRAM deployment.

4.2.1.2.2 Computer Communications

The DECNet-DOS PC communications package, which includes DECNet-DOS communications software and a DEPCA Ethernet card, will be used to monitor and control the network communications requirements of both the on-site EPMIS PC terminals and could also be used to control the remote (asynchronous) EPMIS PC terminals. This software

package allows a PC user to access an Ethernet network, and thus to the data available in a DEC VAX environment, via either a direct Ethernet connection. DECNET-DOS can also run in asynchronous environments with minor modifications.

4.2.1.2.3 Database Communications

At the present time, NEXPERT OBJECT for the PC environment does not have a built-in INGRES database interface. Neuron Data, the company that makes NEXPERT, has plans to develop such an interface in the near future. Code currently exists, as part of the existing XTRAM software, to communicate with the EPMIS database without the use of a NEXPERT built-in interface. This code is presently operational in the current XTRAM implementation and would require only minor modifications to make it functional in the NEXPERT environment. The code uses INGRES/NET which runs under DECNET-DOS protocol to transparently access the EPMIS database on the MICROVAX II. The code is "C"-based containing embedded database queries. The database is queried from inside the "C" routines and the data is converted into "C" variables. At this point, the data is either processed by the "C" routine or loaded into the NEXPERT knowledge base for processing. Permanent copies of EPMIS data are not stored on secondary storage devices on the XTRAM machine due to the necessity of the most recent EPMIS data for XTRAM processing and the dynamic nature of the EPMIS data. When EPMIS data is needed from XTRAM, the main EPMIS database is queried for the most recent EPMIS data.

This code would be used to communicate with the EPMIS database using INGRES/NET, as it does now. When the NEXPERT built-in INGRES interface becomes available, a simple conversion will be necessary to modify XTRAM to utilize the interface.

4.2.1.2.4 User Interface

The combination of NEXPERT OBJECT user interface building tools and "C" graphics libraries, would allow the generation of a graphics/mouse interface.

4.2.1.2.5 Operating System

Of the operating systems available in for 80386 environment (i.e. OS/2, DOS, UNIX/XENIX), DOS is the only one at the present time that can accommodate and support all of the software needed to allow XTRAM to reside on an 80386-based machine. The pieces of software that are necessary for integration that are not available for the other operating systems are DECNet-DOS and INGRES/NET. Many software vendors are currently working towards making their products OS/2 and UNIX/XENIX compatible. If and when DECNet-DOS and INGRES/NET are available for the other operating systems, a review of the implementation of XTRAM on the PC may indicate that XTRAM can be enhanced by switching to one of these more powerful operating systems.

4.2.1.2.6 Multi-tasking Software

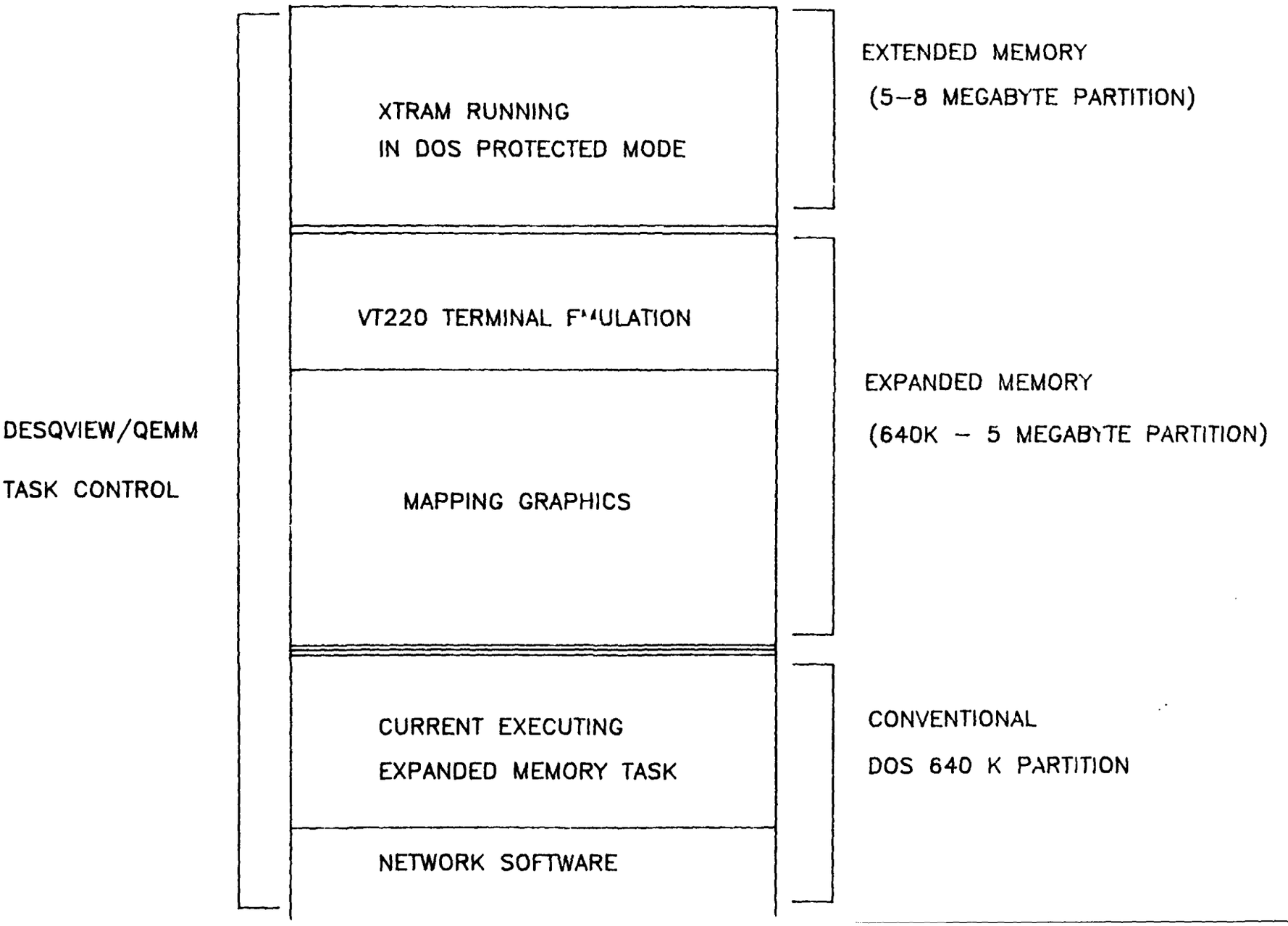
Because a true multi-tasking operating system cannot be used, a multi-tasking software shell is needed to provide a multi-tasking environment. Requirements for multi-tasking using XTRAM on an 80386 machine include a multi-tasking software product that can handle extended memory (DOS protected mode - memory available beyond 640 Kb with hardware limitations of 16 Mb) tasks, as well as expanded memory tasks (requiring less than 640 K per task) running in the DOS environment. A preliminary estimate of the system memory requirements indicates that XTRAM would run in protected mode and that the other tasks would run in expanded memory (Figure 4.2). This is a preliminary estimate, however, and when the tasks are implemented can be optimized to achieve optimum performance once the system becomes operational.

There are several software shells available which allow multi-tasking in a DOS 80386 environment. Desqview and MS-Windows 386 are two of the most popular products for multi-tasking. Of these two products, only Desqview is capable of allowing both protected mode and expanded memory running at the same time. Also, Neuron Data (developers of NEXPERT) used the Desqview memory manager (QEMM) to develop their run-time version of NEXPERT. In addition, Desqview requires less memory overhead and is more efficient than MS-Windows.

4.2.1.3 Computer Networking

Integration Alternative 1 involves having XTRAM run in an 80386 environment concurrent with the Mapping Graphics Enhancement, with

386 DOS MEMORY ALLOCATION



EPMIS running on a MicroVAX II. With the superior processing power of multiple 80386 machines linked to the MicroVAX II, it is very important that the best networking approach be taken so the that network is not the limiting factor, in terms of performance, in the integrated system.

In evaluating the effectiveness of networking alternatives, several functionalities were addressed. The first, and most significant, involves EPMIS database access. The PC-link product by RTI, which is being evaluated for the mapping graphics integration, does provide for data transfer (database queries) from EPMIS to the PC, but does not allow for database updates (PC-EPMIS VAX) which is a requirement of the Mapping Graphics Enhancement. The INGRES/NET product (now functional in the existing XTRAM) does provide bi-directional database communication. XTRAM requires that the database communications between the PC and EPMIS function in both directions. INGRES/NET is therefore the recommended approach for database communications.

The concurrent operation of XTRAM and the Mapping Graphics Enhancement in an 80386 environment means that there could be as many as three tasks running simultaneously during an EPMIS session: XTRAM, the mapping graphics, and a VT-220 terminal emulation (to control the EPMIS user interface on the MicroVAX). To implement the concurrent operation of all three tasks, a communications protocol which allows for multiple parallel communications requests is required.

The integrated EPMIS-XTRAM system should be capable of operating both at the EPMIS MicroVAX II site (local) and from a dial up modem

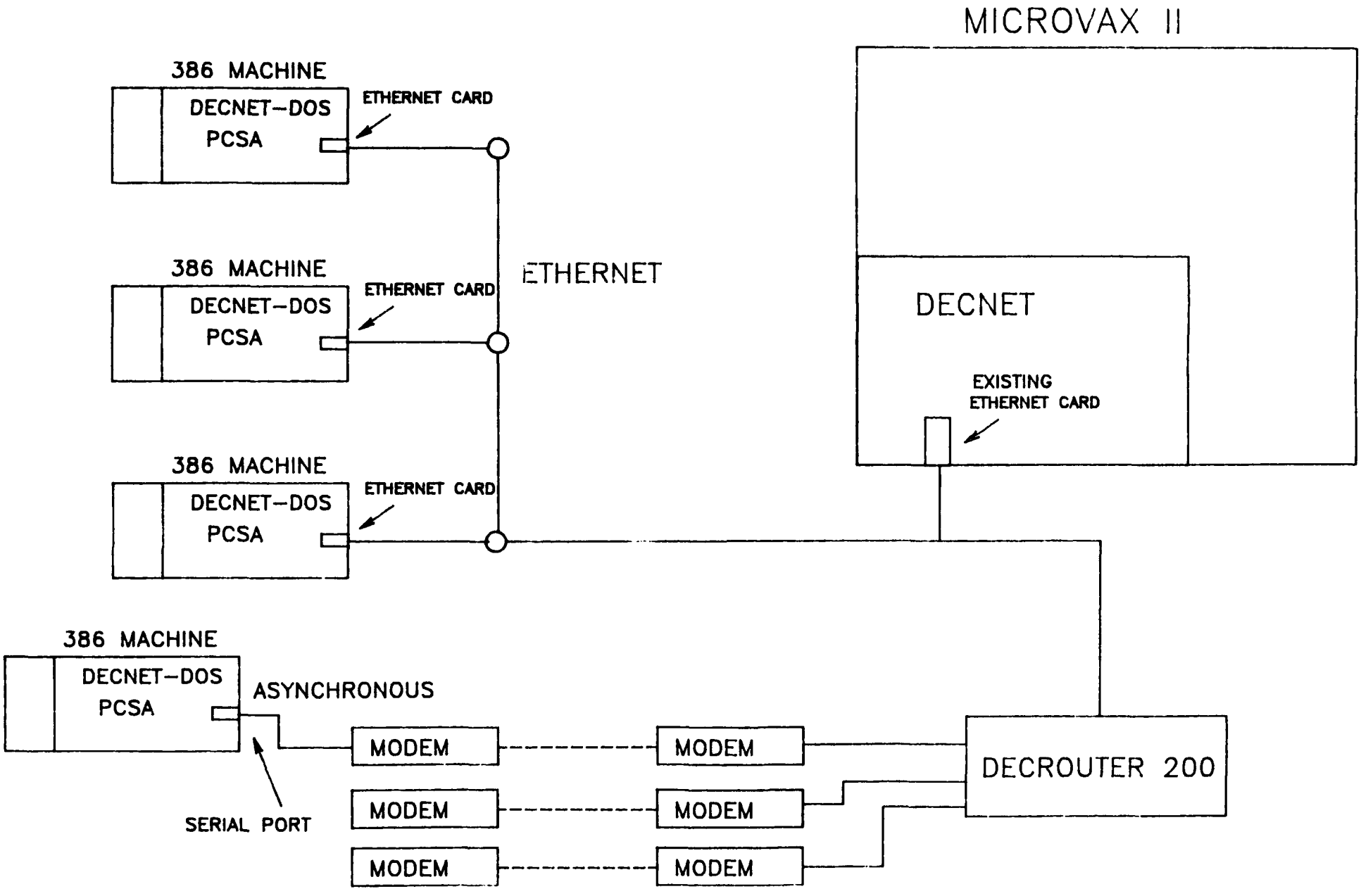
line (fly-away). The selected networking technique should be capable of handling both operating modes with only minor configuration modifications to the PC environment. From an evaluation of the networking packages available for the combined VAX-PC environment, the following computer networking strategy was selected for the EPMIS-XTRAM integration Alternative 1 system.

For database communications, INGRES/NET would be used. INGRES/NET provides a bi-directional transparent access to databases on remote computers. A program written and running on a PC can contain an embedded database query or update call. EPMIS data can then be directly inserted into the XTRAM environment. The current XTRAM system uses INGRES/NET for its database queries and updates in its current VAXstation II to MICROVAX II communications.

The on-site PC-to-MicroVAX II communications would be implemented using DEC's Ethernet network. This approach involves the use of a DECNet-DOS communications package for the PC. The package includes a DEPCA card (which is an Ethernet card for the PC) and DECNet-DOS network software.

The DECNet-DOS software will run under DOS 3.3 and will control all requests for communications through the Ethernet card (at 10 Mbps). All of the on-site 80386 machines will be physically connected to the existing Ethernet card in the MicroVAX II. Figure 4.3 illustrates the on-site configuration. The MicroVAX will be set up as the file server in the network, providing transparent PC-to-VAX file access.

NETWORK CONFIGURATION – DECNET DOS



For remote operation, a DECrouter 200 communications device could be attached to the MicroVAX II's Ethernet card. This would allow for remote machines to dial into the network and provide the same functionality as the on-site PCs, limited only by the modem transmission rates employed. The only modifications required for remote operation would be configuring the PC's DECNet-DOS network software to access an asynchronous RS-232 serial port on the machine instead of the Ethernet card (an Ethernet card will not be required for the remote PCs). The integrated EPMIS-XTRAM remote operations could have the same functionalities as the on-site systems with somewhat reduced performance due to the limitations of modem communications speeds.

An alternative to the above-mentioned remote operation configuration would employ one of several available modem software packages which would speed the remote processing considerably. The modem software would send commands to a dedicated 80386 machine located at the same site as the EPMIS database server, connected to the MicroVAX II via the Ethernet network. The 80386 machine would actually perform the processing, and only the user interface input and output screens would have to be transferred over the asynchronous communications line. This option would provide a dramatic increase in remote processing speeds by eliminating the large data transfers over the modem lines. The remote system would only require minimal 80286 capabilities (to support VGA) and thus could be implemented in a portable or laptop configuration.

4.2.2 Cost/Performance Evaluation

The EPMIS-XTRAM integration Alternative 1 system is an excellent price/performance alternative. In this alternative, a more powerful version of the Mapping Graphics Enhancement 80386-based EPMIS PC terminal would be employed to implement XTRAM (concurrent with the Mapping Graphics Enhancement). The cost of the additional PC performance required (both hardware and software) is approximately $10,000; this is more than offset by the large increase in processing power. The added processing power of the 80386-based PC (5.5 - 6.5 MIPS), in addition to that of the EPMIS MicroVAX II (0.9 MIPS), will give the integrated system a significant boost in performance.

The XTRAM processing is fully implemented on the more powerful PC and thus will not interfere with EPMIS performance on the MICROVAX II. Only database accesses required by XTRAM (and the Mapping Graphics Enhancement) will occur on the MICROVAX II. When multiple EPMIS/XTRAM users are using the system, XTRAM will be processing on multiple 80386 machines (5.5 MIPS each) instead of multiple XTRAM processes running on a single MICROVAX II (0.9 MIPS). The relative price performance for this alternative is the cost of additional hardware ($4,745) divided by 6.4 MIPS (5.5 for 80386 + 0.9 for MICROVAX II) = $741 per MIPS.

Another advantage this alternative provides is that XTRAM would already be developed for the fly-away application when the technology becomes available. Migration from the non-portable 80386-based PC into a portable environment (possibly 80486-based) would require only a minimal effort. One disadvantage this alternative poses is that it

requires a communications network to transfer data between XTRAM and EPMIS; however, a bi-directional MicroVAX-to-PC database communications bridge is already required for the EPMIS to mapping graphics communications.

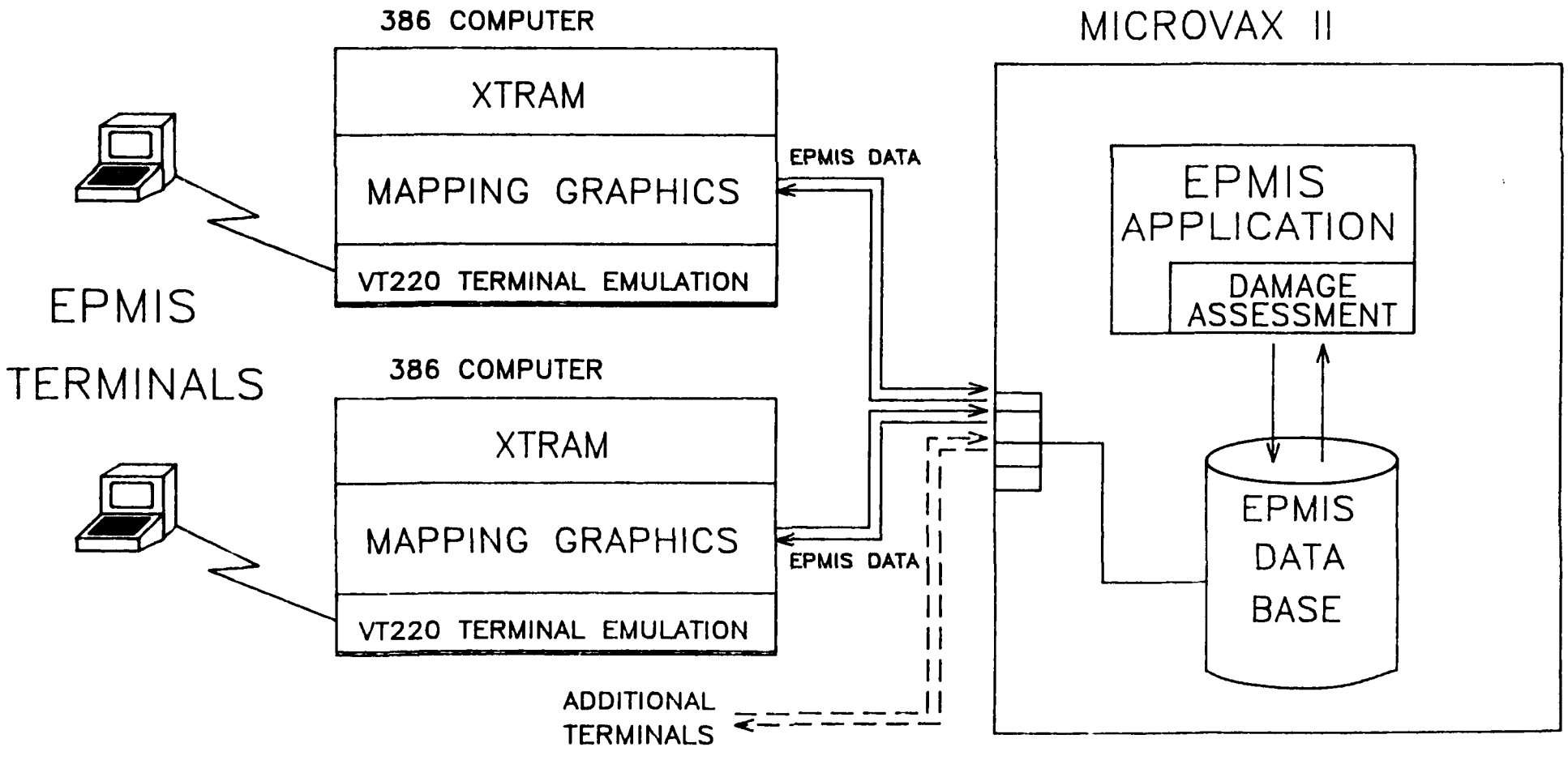
4.2.3 System Design Specification

Implementation of this alternative involves XTRAM residing on the EPMIS 80386-based PC. The user would access the XTRAM system through a Desqview multi-tasking window; XTRAM would, in turn, access EPMIS via either Ethernet or an asynchronous serial connection. Figure 4.4 is an illustration of the EPMIS-XTRAM integration Alternative 1 system.

The current plan for the EPMIS PC environment is to employ an 80386-based PC with a clock speed of 20 MHz. The implementation of XTRAM on the PC, concurrent with the Mapping Graphics Enhancement, will require the processing power of a 25 MHz machine. The additional cost of the 25 MHz PC over the cost of the 20 MHz PC is approximately $4,000 (see summary below). This fact should be taken into consideration in the integration of the Mapping Graphics Enhancement with EPMIS as this integration will be performed prior to the XTRAM integration.

The implementation of this alternative would require a 25Mhz 80386-based PC, DECNet-DOS communications package, the NEXPERT OBJECT expert system development tool for the PC (along with run-time module and one year of maintenance), INGRES for the PC (including INGRES-NET), the MS-Windows 386 (necessary for NEXPERT development) and

XTRAM INTEGRATION PLAN 1



Desqview 386 multi-tasking environment packages, and the MicroSoft "C" programming development environment. A summary of the items required to implement this alternative is listed below.

Hardware

25 MHz 80386-based PC	15,500**	
20 MHz 80386-based PC	(11,650)	
Difference		3,850
DECNET-DOS communications package		895

Software

NEXPERT OBJECT (including licenses)	7,070
INGRES for PC	1,295
Microsoft "C"	450
Desqview	200
Total Cost	13,760

4.3 Alternative Number Two

4.3.1 System Design

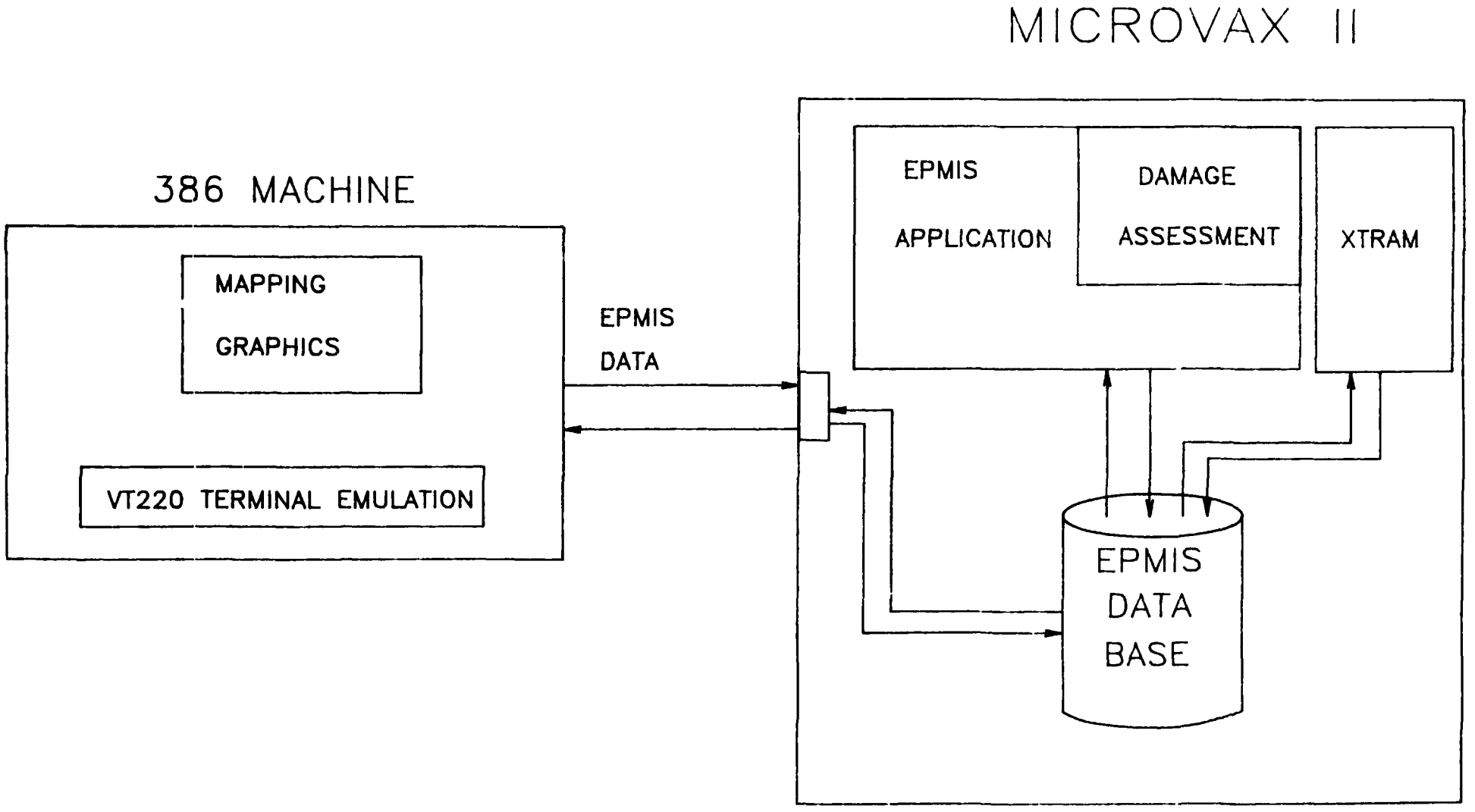
The second alternative consists of XTRAM executing in the existing MICROVAX II. The XTRAM program would share the MICROVAX computer resources. This configuration is illustrated in Figure 4.5.

4.3.1.1 Hardware

In this alternative, the existing MICROVAX II hardware would be used for the EPMIS/XTRAM integration. This alternative would require upgrading the memory and disk space of the MICROVAX II to attain a

** The 25 MHz PC price used here is for the most expensive configuration.

SYSTEM ALTERNATIVE 2



total of 13 Megabytes of RAM and 318 Megabytes of disk space. With XTRAM running in the same environment as EPMIS, the system memory should be increased to reduce any paging or swapping that may occur due to a lack of physical memory.

4.3.1.2 Software

4.3.1.2.1 Expert System Shell

NEXPERT OBJECT is an expert system shell that runs on a variety of platforms. As mentioned in Alternative 1, NEXPERT's "C" based implementation has enabled NEXPERT to be transported to the DEC VAX, IBM PC, Apollo, Sun, and IBM mainframes. In addition, it is 95% source code compatible across hardware platforms as a result of its "C" implementation. The only differences across hardware platforms are subtle user interface differences.

Also as mentioned in Alternative 1, NEXPERT OBJECT shares several similarities with ART that will facilitate the conversion of the XTRAM software from the LISP-based ART to the "C"-based NEXPERT. These similarities include a frame based knowledge representation and a data driven architecture. NEXPERT has a robust user interface for development, and an extensive user interface development tool for building a custom user interface for an application.

Although the use of NEXPERT would require coding changes regarding rule conversion, the user interface coding would be much simpler compared to that of other expert system shells. The conversion to NEXPERT would make XTRAM very portable, an important feature if an EPMIS hardware platform change were made in the future.

In addition to the features previously mentioned, NEXPERT can also be easily embedded into existing applications. The ability to easily embed one application into another is an excellent feature that can be used to physically link programs together in one environment. The VAX version of NEXPERT also features a built-in INGRES database interface for easy expert system/database communication.

4.3.1.2.2 Database Communications

The NEXPERT OBJECT product on the VAX has built-in INGRES database interface capabilities. Although code already exists from the current implementation of XTRAM to interface with the INGRES database, the built-in interface would be used to provide for easy software maintenance.

4.3.1.2.3 User Interface

Interface Option 1:

NEXPERT has a product which allows for the execution of the expert system on one computer, while the user interface exists on a different computer. In this case, the expert system would run on the MICROVAX II and the user interface would reside on the 80386 machine. Using this capability, a graphics/mouse user interface would be available, and look almost identical to the user interface of alternative 1.

The only difference, as far as the user is concerned, between integration Alternatives 1 and 2 would be that the physical execution

of XTRAM would be taking place on the MICROVAX II. This alternative would require some XTRAM integration development in an 80386 environment, closely coordinated with TITAN systems, as the XTRAM user interface would reside in the same computer as the mapping graphics module.

Interface Option 2:

A second option for a user interface for this alternative would be to use the NEXPERT text user interface building tool for the VAX (VT220). This environment would consist of text windows and cursor controlled scrolling using cursor (arrow) keys instead of a graphics display with mouse control. This approach would not require any XTRAM integration development in the 80386 environment. The user interface would function in a VT220 environment handled by the VT220 terminal emulation on the 80386 terminal.

4.3.1.2.4 Operating System/Multi-tasking Software

In the current EPMIS MICROVAX II configuration, the VMS operating system is used. VMS is a true multi-tasking operation system. Multi-tasking would be achieved in a VT220 environment by using VMS spawn and subprocess commands to create a process running in the background (XTRAM) while the user has control over the terminal running another process (EPMIS).

4.3.2 Cost/Performance Evaluation

In this alternative, the existing MICROVAX II with the proposed additions of memory and disk space would be used for integration. The enhancements to the MICROVAX would cost approximately $11,500 assuming that the current MICROVAX presently has 5 Megabytes of memory and 142 Megabytes of disk space (current specifications EPMIS MICROVAX communicating with current XTRAM). If three users are using the MICROVAX II concurrently, there is the potential for three XTRAM sessions running at the same time. In this scenario, each user would receive 1/3 of the 0.9 MIPS of the MICROVAX CPU. At worst case, 3 users running XTRAM in the background could potentially perform damage assessment. In this scenario, each task, XTRAM and damage assessment would share the MICROVAX CPU. Both XTRAM and damage assessment tasks must also perform database accesses as part of their respective tasks.

At best case only one user would be logged on to the system, running the XTRAM program only. In this scenario, the user would receive the full .9 MIPS of performance. Even in this case, .9 MIPS of performance with XTRAM and the database accesses occurring in the same machine is not the best performance available considering the computing resources (MICROVAX II and 80386) available. The relative price performance for this alternative is the cost of additional hardware ($11,500) divided by .9 MIPS = $12,777 per MIPS.

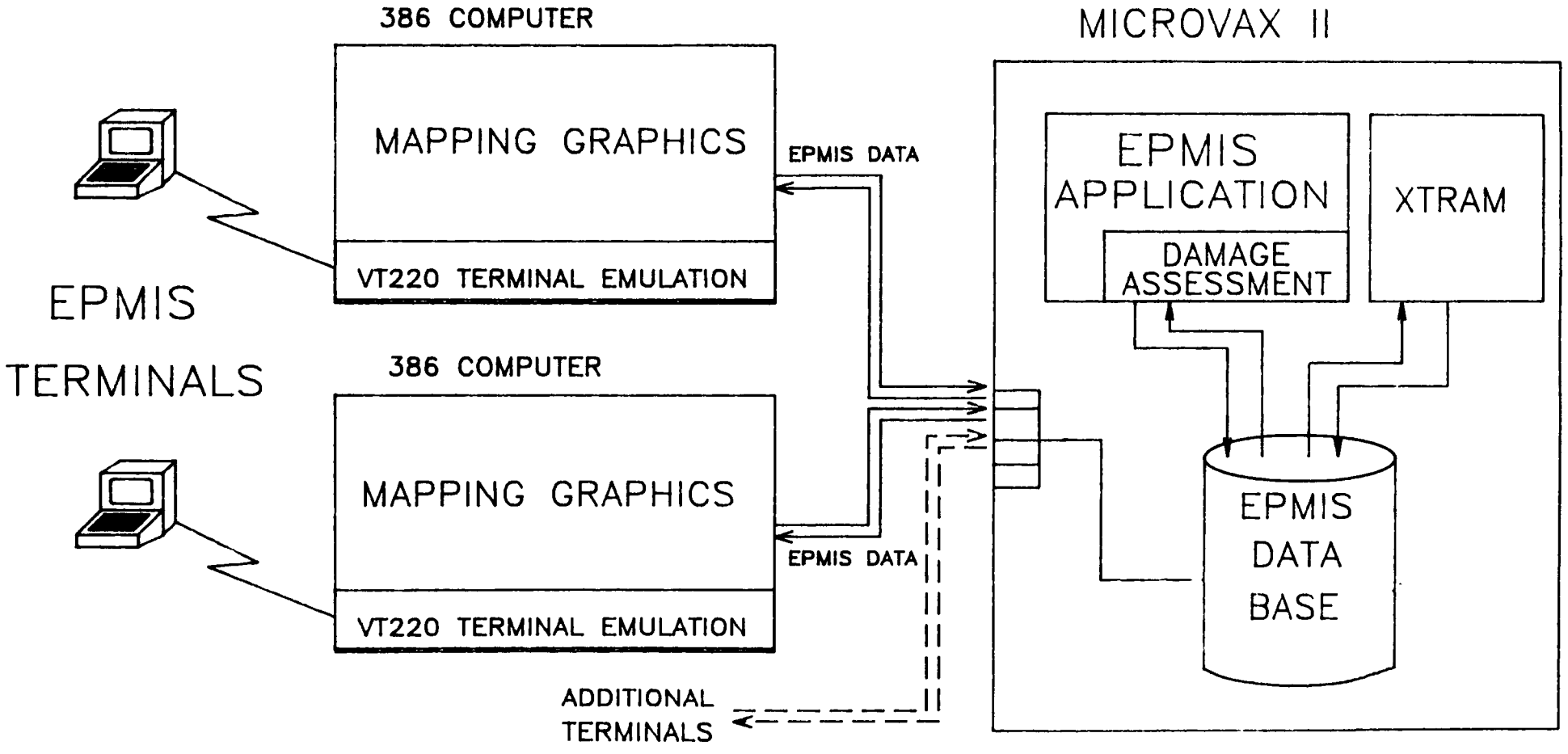
4.3.3 System Design Specification

Implementation of this alternative involves XTRAM residing in the MICROVAX. The user would access the XTRAM system from the 80386 terminal using VT220 terminal emulation. A system configuration is illustrated in Figure 4.6.

The implementation of this alternative would require additional disk and RAM resources for the MICROVAX II, the NEXPERT OBJECT expert system development tool. A list of items necessary for integration and their costs are listed below.

Hardware	
Additional Disk 159M disk for MICROVAX II RD54	$5,395
8M additional RAM for MICROVAX II	$6,000
Software	
NEXPERT OBJECT expert system shell with 1 year of maintenance (including runtime)	$10,570
Monthly Maintenance for Memory and Disk	$130

XTRAM INTEGRATION PLAN 2



4.4 Analysis

The issue which clearly separates the two alternatives mentioned above is performance. Of the two system alternatives mentioned, the first consists of XTRAM running on a 80386 PC connected to the MICROVAX II, and the second consists of XTRAM running on the MICROVAX II along with EPMIS. From a performance point of view, no matter which alternative is chosen, a considerable increase in XTRAM performance in a standalone mode on the MICROVAX II (with nothing else running) would be realized using the new "C" based NEXPERT vs. the current LISP based ART implementation. The performance increase in using NEXPERT vs. LISP based ART is estimated at approximately 3 to 4 times the current performance level.

When considering the 80386 vs. the MICROVAX II approach, however, the performance of the 80386 approach should be significantly higher due to the higher processing speed of the 80386 (even when the overhead of the data link is taken into consideration). The performance increase in using NEXPERT on a PC is estimated at 10 to 15 times the present XTRAM performance level.

As more users, each potentially using XTRAM, use the system, more processing power becomes necessary. The processing of XTRAM (possible multiple XTRAMs) in the MICROVAX II, along with EPMIS data requests from the damage assessment and mapping graphics modules, would not only severely degrade XTRAM performance, but also degrade performance of the other modules which access the EPMIS database.

The added processing power of a 80386 in addition to the MICROVAX II will give the entire system added performance. XTRAM

will not interfere with EPMIS performance on the MICROVAX II. Only database accesses required by XTRAM will occur on the MICROVAX II. When many EPMIS/XTRAM users are using the system, XTRAM will be processing on multiple 80386 machines (5.5 MIPS each) instead of many XTRAM processes on a single MICROVAX II (0.9 MIPS).

Alternative 1 also has an advantage in that its XTRAM would already be in place (PC environment) for future fly-away implementation. Another step of migration of XTRAM into a portable environment in the future would be unnecessary. One potential disadvantage for alternative 1 involves the networking an communications necessary for the approach, however, a bi-directional database network/communications scheme of some type must be implemented for the mapping graphics module regardless of which XTRAM integration alternative is chosen.

Even though the performance of Alternative 2 is less than that of Alternative 1, the performance of Alternative 2 can be increased by migrating to a more powerful VAX with more processing power. This migration could be made with total software compatibility (no modifications to XTRAM). This migration compatibility is one the major strong points of the VAX family of computers.

Table 4-4: Comparison of System Alternatives

	Alternative 1 80386	Alternative 2 MICROVAX II
Combined Processing Power	7 MIPS	0.9 MIPS
Cost	$22,000	$22,000
Cost per MIPS	$3400/MIPS	$24,000/MIPS
Portability Potential	Excellent	Fair
Transparent Software Migration	NO	YES
Estimated Response time vs. Present	10 times faster	Same

4.4.1 Recommendations

Of the two alternatives described, alternative 1 is recommended for XTRAM integration. With the advantage in both price/performance and accommodations for future plans, the 80386 XTRAM technique outweighs the MICROVAX approach.